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Forecasting the diffusion of renewable electricity considering the impact of policy and oil prices: The case of South Korea

Chul-Yong Lee [a], Sung-Yoon Huh [b,*]

[a] Korea Energy Economics Institute (KEEI), 405-11 Jongga-ro, Jung-gu, Ulsan 44543, South Korea
[b] Haas School of Business, University of California Berkeley, 2220 Piedmont Avenue, Berkeley, CA 94720, USA

HIGHLIGHTS

- Analyzes influence of government policy and oil price on renewable electricity diffusion.
- Applies innovation diffusion model to South Korea' renewable electricity market.
- Uses scenarios to predict diffusion pattern of renewable electricity in South Korea.
- Finds renewable electricity generation is influenced by RPS implementation and oil price.
- 40.4–85.9 TW h of renewable electricity generation are predicted in 2024.

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ABSTRACT

In response to climate change, many countries have set renewable energy targets and implemented various policy tools. However, there are contrasting views on the effects of such policy tools, with many deeming international oil prices a potential factor driving renewable energy diffusion. Using an extended logistic growth model, this study aims to investigate this issue and predict the impact of policy tools and oil prices on renewable energy deployment in the electric power sector under various scenarios. The results show that the renewable portfolio standards more significantly influence the diffusion of renewable energy than the feed-in tariff in South Korea's electric power sector and higher international oil prices have led to higher diffusion rates. The forecast indicates that South Korea will generate 40.4–85.9 TW h of renewable electricity by 2024 depending on the scenario. The results also indicate that the renewable electricity diffusion rate will continue to increase by 2024, proving that the current diffusion is in its initial stage. The study concludes with implications for the government, which has a crucial role in the initial phase.

1. Introduction

In recent years, there have been continuous efforts worldwide to reduce carbon emissions. At COP21, held in Paris in 2015, 196 countries were designated mandatory reduction targets, regardless of whether they were developing or advanced countries. Consequently, many countries signed the INDC and implemented policy tools to accomplish its associated goals. Renewable energy is important as an alternative energy source to not only cope with climate change but also enhance energy security and develop a new industry. Globally, research and development, and policies for the diffusion of renewable energy are being promoted. As of 2014, renewable energy accounts for 19.2% of the final global energy consumption and its growth in capacity continues. The average annual growth rate of the capacity of each source from the end of 2010 through 2015 is 42% for solar PV, 35% for CSP, 17% for wind power, 3.7% for geothermal power, and 2.9% for hydropower [1].

To predict the feasibility of each nation's diffusion goals, and design deployment policies and technology development strategies related to the renewable energy lifecycle, it is first necessary to determine the mid- and long-term supply of renewable energy. Previous studies attempted to forecast renewable energy deployment using methods such as market simulation [2], real options [3], artificial neural networks [4], diffusion modeling [5,6], and bottom-up models [7,8].

To forecast renewable energy deployment accurately, it is crucial to identify socioeconomic factors affecting renewable energy diffusion. In particular, analyzing the determinants of renewable

* Corresponding author.
E-mail addresses: cylee@keei.re.kr (C.-Y. Lee), sunghuh@berkeley.edu (S.-Y. Huh).

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Nomenclature

Bbl	barrel
CO_2	carbon dioxide
COP21	the 21st conference of the parties
CSP	concentrating solar power
GDP	gross domestic product
EIA	US Energy Information Administration
FIT	feed-in tariffs
IEA	International Energy Agency
INDC	Intended Nationally Determined Contribution
OECD	Organisation for Economic Co-operation and Development
PV	photovoltaic
REC	renewable energy certificate
RES-E	electricity from renewable energy sources
RPS	renewable portfolio standards
WTI	West Texas Intermediate

energy deployment and quantifying their effects are important tasks for forecasting and controlling the diffusion process of renewable energy. Various studies investigated the determinants of renewable energy deployment such as carbon emissions [9–11], macroeconomic factors [12], GDP [10,13], economic and financial development [14], traditional energy sources [9], and trade openness [11]. These studies can be classified into panel and time series analyses, those focusing on developed and developing countries, investigations of individual variables, and examinations of various types of renewable energy [14].

One of the most important factors influencing renewable energy diffusion is policy implementation by governments. Despite steady technological innovation, it is difficult to deploy renewable energy using voluntary market mechanisms effectively, owing to its low economic efficiency compared to traditional energy sources. Therefore, national- and state-level policies play important roles in the effective promotion and diffusion of renewable energy. In particular, many countries are adopting the FIT and RPS, which are key policies aimed at the diffusion of RES-E. However, despite numerous existing studies on the effect of these policies, there remain contrasting opinions on which policy is more effective [15–21].

In addition, the price of traditional fossil-based energy, which can be represented by oil prices, is another potential factor affecting the diffusion of renewable energy. Oil prices can affect the development of renewable energy in both the transportation and electric power sectors [22]. However, research on the relationship between oil prices and renewable energy penetration present contrasting results [23–25]. Thus, an investigation of their relationship in each market is necessary.

This study examines the influence of potential factors on the diffusion of RES-E, focusing on policy implementation and oil prices, among various determinants. In addition, it attempts to identify which policy between FIT and RPS shows better performance for the diffusion of RES-E. The study estimates a forecasting model using data on RES-E, policies, and international oil prices, and thereby forecasts the mid- and long-term diffusion of RES-E. An extended logistic growth model, which is an innovation diffusion model, examines the influence of the factors of interest on the diffusion of RES-E and forecasts diffusion patterns; specifically, the model is applied to RES-E in South Korea, which has experienced both FIT and RPS policies. Using the forecasting results for various scenarios, the study will examine the achievement of South Korea's mid- and long-term goals of RES-E and present the implications of relevant policies. Another key contribution of this study is that the proposed model can be modified to fit any market or situation in other countries.

Section 2 reviews the literature on factors influencing the expansion of renewable energy and issues of renewable energy policies and oil prices. In Section 3, the extended logistic growth model explains the influence of policies and oil prices on the diffusion of RES-E and a model application in RES-E is presented. Section 4 describes the data used in the analysis. Section 5 provides empirical results and presents South Korea's mid- and long-term prospects of RES-E, according to the model estimation and a scenario setup, followed by discussions. Section 6 summarizes the findings, highlights the study's limitations, and proposes opportunities for future research.

2. Literature review

2.1. Impact of policies on renewable energy markets

Various renewable energy policies were implemented since the late 1990s and early 2000s given the growing interest in and public support for renewable energy. The number of countries establishing renewable energy policies and supply targets has steadily increased. By the end of 2015, 146 countries implemented renewable energy support policies and 173 nations set policy targets at the national or state level [1]. The key factors motivating the adoption of renewable energy policies are responding to climate change, decreasing fuel import dependency, diversifying energy sources to respond to external changes and shocks, and dominating future technology markets. However, renewable energy policies have mainly focused on the electric power sector [26]. That the number of renewable energy policies in the electric power sector is far greater than in other sectors confirms this.[1] This is attributable to the implementation of important renewable energy policies, such as FIT and RPS in the electric power sector, and the development of most policy tools based on previous power sector policies.

Most studies affirm that policies play a critical role in influencing renewable markets. The level of influence and efficiency of individual policies, and specifically, an individual policy's effect on a factor in the renewable energy market are some major concerns addressed in various studies. Polzin et al. [27] organized previous studies on the relationship between policies and renewable energy deployment and categorized these policies into fiscal policies and financial incentives, market-based instruments, fund provision, policy instruments related to investment decisions, and regulatory measures. Recent studies note that a single policy is insufficient; therefore, a policy mix of complementary instruments is necessary [27–31]. For example, del Río and Mir-Artigues [29] addressed the need for combinations of instruments for RES-E, as a single instrument cannot tackle multiple market failures simultaneously. Fagiani et al. [30] found that a single policy is cost-inefficient in increasing RES-E. Yoon and Sim [31] also noted that using a varied policy mix is important for promoting the development of renewable energy in South Korea.

Focusing on which factor a policy intervention affects in the renewable energy market significantly varies by study. For

[1] By the end of 2015, 114 countries implemented power policies, 66 countries enacted transport policies, and 21 countries applied heating and cooling policies [1].